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AN EVALUATION OF THE ONTARIO LARGE ENERGY USER DATABASE

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Chapter 1

INTRODUCTION

The switchable fuel market constitutes an important but largely unexplored component of Canada's energy consumption profile. Certain types of energy-using equipment are capable of switching between two or more fuels, based on dual- or multiple-fuel technologies. This is particularly prevalent in steam-raising applications. The capacity to switch between energy forms is constrained by the existing storage and handling systems for alternate fuels, and also by the extent to which adjustments or retrofits to the operating equipment are required in order to facilitate such transitions between fuels.

Considering the importance of understanding the extent and nature of the fuel flexibility in end-use markets, the lack of any comprehensive information in this area has been a definite shortcoming. Such data is important for understanding and anticipating short-term demand fluctuations, but also for long-term strategic planning. For example, fuel flexibility data has been collected to determine the actual consequences of supply shortages for oil.

A database based on a survey of large energy users in Ontario now exists. This report analyses the content and quality of this database. The problems and inconsistencies uncovered in the database have not been corrected, nor has a new computer program to generate aggregate results for the database been written. A computer program was generated under the consulting contract by which the data was collected, but was only made available in a compiled form to the Institute. **The scope of this report was therefore limited to a critical investigation of the database with a view to providing specific recommendations for further work.**

1.1 Database Background

In the interest of collecting a detailed database on energy consumption patterns, including information on the characteristics of energy using equipment, six clients commissioned a consulting company to undertake a survey of large energy users in Ontario.[1] The survey gathered information on energy consumption in 1987 by large

mining and manufacturing companies and by large hospitals and universities.[2]

In order to ensure both confidentiality for survey participants and public access to the aggregate results, the contract stipulated that, once completed, the database should be stored at and accessed through the Canadian Energy Research Institute.

1.2 Report Objective

The original intention of the survey was to eventually extend it to include all the provinces in Canada. In light of this, it becomes particularly important to undertake some analysis and evaluation of the results obtained for Ontario in the initial survey. This report attempts to gauge the quality of the data and make recommendations for modifications or additions to future surveys.

1.3 Report Outline

Chapter 2 contains a description of the database content and characteristics. Unlike other data sources, the survey was intended to collect a large volume of detailed information, including switching capability among all fuels rather than isolating one or two energy forms. In addition, energy volumes were divided into firm and interruptible service for both natural gas and electricity and into purchased and used volumes for all energy forms.

In Chapter 3 the overall conclusions and recommendations are presented. Particular interest has been expressed in the possible uses of the data as a basis for modelling work to address a range of research topics, such as forecasting energy requirements for steam raising and future cogeneration potential. Recommendations are made for future changes and additionsto the database to facilitate such work. Appendix A contains a copy of the original survey questionnaire.

Footnotes

[1]The clients of the survey were: Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources Canada; Energy Conservation Branch, Energy, Mines and Resources Canada; Renewable Energy Branch, Energy, Mines and Resources Canada; Industrial Programs Branch, Environment Canada; Economics Branch, National Energy Board; and Ontario Ministry of Energy.

[2]CERI Energy Research Ltd., *Energy Use Patterns and Boiler Characteristics of Large Energy Users in Ontario*, Multi-Client Study (Calgary, Alberta: CERI Energy Research Ltd., May 1989). NOTE: CERI Energy Research Ltd. was a consulting company established with the assistance of the Canadian Energy Research Institute. The name of the company was changed to Calgary Energy Consultants Ltd. in 1989 and it was sold. Calgary Energy Consultants Ltd. has no relationship with the Canadian Energy Research Institute..

Chapter 2

CONTENT AND CHARACTERISTICS OF THE DATABASE

Collection of reliable data by survey is a difficult and arduous undertaking. The steps involved that are of critical importance to the quality of the data can be roughly broken down as follows:

- selection of a target population;
- design of the survey questionnaire;
- checking and follow-up of returned questionnaires;
- coding of responses to create the database;
- design of a computer program to produce aggregate results; and
- interpretation and analysis of the final results.

The quality of the final database depends on the accuracy, consistency and expert knowledge employed in every one of these steps. Perhaps the most important premise for a good survey is to have adequate knowledge of the universe to be surveyed, in this case the large energy using industries and institutions in Ontario. This evaluation and criticism does not include a presentation of independently generated database results, except where these provide an indication of the validity of the data. Some aggregate results from the consulting company's report have been included for illustrative purposes.

2.1 Questionnaire Design and Collection

The target population is usually selected as a sample of the universe of the entire population. A sample should be constructed such that conclusions about the behaviour or characteristics of the universe can be drawn based on observations from the sample. It is important in this respect to differentiate between the coverage and the response rate figures. Coverage is understood to refer to the portion of the universe contained in the final database. Response rate, on the

other hand, is the portion of the target population that returned the surveys.

It appears from the methodology description that the approach taken was not to collect a sample, but rather to cover as closely as possible the universe of all large energy users. This was an ambitious undertaking, because Ontario has such a large and diversified industrial base.

2.1.1 The Target Population and Response Rates

A target population of 373 large energy users in Ontario was approached, and almost 70 percent of the surveys were returned. An inconsistency between the 260 records listed in the database and the response rate of 255 records reported in the consulting study cannot be completely resolved without access to the source code that generated the report results. On investigation of the database it appeared that two record numbers existed in duplicate and one in triplicate, but as these repeated records contained different data, it was not immediately apparent which, if any, should be deleted.

In addition, some records contained so little data that their contribution to the aggregate results is negligible. For example, the first question, A1, records total volumes of energy purchased and used. An accurate and complete response to A1 is particularly important, as the responses to the next two questions are reported in percentage format, relying on the volumes recorded under A1 to calculate volumes used in each end-use category and volumes of switchable fuels. There are four records in the database that contain no positive number as the answer to the first question.

A further qualification of this response rate is called for as no single question or variable in the database obtained a quantifiable answer from all of the respondents. Table 2.1 contains an overview of the response rates to individual questions. It must be kept in mind that a 50 to 70 percent response rate on a survey is generally considered a very reasonable result. Also, since some questions will not apply to all respondents, on any one question response rates must be expected to be lower than the total for the questionnaire. Response rates for individual questions will be further explored in Sections 2.2 through 2.7.

TABLE 2.1

SURVEY POPULATION AND RESPONSE RATES

Survey Population:	*Industrial Companies*	*298*
	Institutions	*75*
	Total	*373*

		Total Number of Positive Unique Responses	Percent of Survey Population
Total for Survey		256	69
Question A1	- Purchased Energy	252	68
	- Used Energy	5	1
Question A2	- All Categories	243	65
	- Excluding "Other"	213	57
Question A3	- All Categories	152	41
	- Excluding "Other"	82	22
Question A4	- sulphur	98	26
	- heat	99	27
	- storage	130	35
Question A5	- yes/no response	31	8
	- volume response	24	6
Question B1		177	47
Question B2		170	46
Question B3		176	47
Question B4		173	46
Question B5		179	48
Question B6		159	43
Question B7		145	39
Question B8		141	38
Question B9		162	43
Question B10		172	46
Question B11		146	30
Question B12	- yes/no response	9	2
	- volume response	4	1
Question B13		26	7

2.1.2 Coverage of the Universe

It is difficult to evaluate the institutional data, as this classification does not correspond directly with any other common category for data. It represents, for example, only a fraction of the commercial sector. The universe of hospitals and universities is known and was exhaustively covered. The indicated response rate of 57.3 percent should therefore be an accurate reflection of the actual coverage. It should be noted, however, that these two are not the only types of institutions that consume a substantial amount of energy, and that the university category also contains several smaller colleges. An error was also found in that one hospital record is missing from the database, although it is recorded as received. This reduces the coverage to 56 percent from the number listed in the client report.

A more serious qualification must be made with respect to the industrial users category. The source of this survey population was the list of companies from Statistics Canada's Census of Manufacturers. It should be noted that Statistics Canada have recently changed the name from Census to Survey of Manufacturers, based on an expressed lack of confidence in the quality and coverage of the list of manufacturing establishments. In spite of this, the list is probably the best available source of companies and the additions and checks made should have further improved the coverage of industrial establishments.

According to the National Energy board, industrial sector energy purchased in Ontario in 1987 totalled 848 000 terajoules.[1] In addition, 224 000 TJ of energy was purchased for non-energy purposes, in other words feedstock applications such as coal and coke to iron and steel establishments and natural gas to chemical plants. Total energy purchased, including feedstocks, according to the question A1 in the survey was approximately 545 500 TJ.[2] This leads to the conclusion that approximately 50 percent of industrial sector energy use is covered by the database.

A further indication of the coverage is found by calculating the feedstock volumes recorded in Question A2 as an end-use category. Approximately 91 750 TJ of feedstocks are recorded in the database, constituting just over 40 percent of the non-energy end-use reported by the National Energy Board.

In conclusion, the low response rate to some of the questions and a poor understanding of the universe of large industrial users

mean that the coverage of the industrial sector is less satisfactory than indicated by the reported 70 percent response rate. The absence of comparable data makes it difficult to estimate actual coverage but, according to the purchased energy volumes reported, approximately 50 percent of industrial energy purchases appear to have been covered by the survey.

2.1.3 General Coding Problems

With all survey responses it is necessary at an early stage to decide how to treat the blanks on the questionnaire. Lack of response to a certain question or variable can be interpreted three different ways:

- the question is not applicable to that company, for example, they never use natural gas in their boilers;
- the quantities consumed were zero for the time period in question, in other words their boilers did not burn natural gas during 1987 but may do so at another time; or
- the company is unsure or prefers not to divulge the quantity of that variable, in other words some unknown but positive volume of natural gas was burned in their boilers.

A special code, -99, was invented for the purpose of distinguishing between a "zero" and a "not applicable" response. It was assumed that a distinction could be determined through follow-up work and analysis of the other responses from the same company. Not only did this prove to be difficult but a number of people carried out the computer coding and confusion appears to have existed as to whether -99 was to be used for the "not applicable" or the "unavailable" response.

Whether as a result of inadequate follow-up, inconsistent coding, or reluctance by the companies to divulge the data, the result is that the database is filled with a mixture of blanks, zero and -99 responses and no consistent interpretation can be applied to these.

2.1.4 General Considerations in Questionnaire Design

Designing a good questionnaire is a difficult task under the best of circumstances. The basic conflict arises between a desire to obtain detailed and previously unrecorded data and a necessity to keep

the questionnaire as short and simple as possible to ensure a good and accurate response.

This questionnaire appears to have succeeded in structuring the data in accordance with industry conventions, such that answers could be found with a minimum of work by the companies. However some questions, notably in Section A, are too complex, integrated and lengthy. A simplification would have improved both the response rate and the accuracy of the data. Long and complex questions require long and complex instructions and the possibilities for errors are multiplied.

There is also a danger in creating too much dependency among questions. The best example of this is the already mentioned dependency on Question A1, recording volumes purchased and used, in order to assign volumes to each end-use and switchable volumes. These details were recorded as percentages of the volumes in A1. If A1 is to play such a crucial role it is very important that this be a clear and simple question to avoid compounding errors. While it is true that this dependency among questions ensures consistency in the database, this is not a consistency based on confidence in the responses being correct or on thorough checking of the returned questionnaires. The consistency is created by the structure of the questionnaire and does not enhance our confidence in the data.

A good questionnaire should be structured such that the consistency between responses can be checked and, if necessary, the data corrected. To build in consistency between responses without an adequate checking mechanism increases the possibilities of compounded errors.

With these general comments in mind, the remainder of this chapter addresses the structure, response and problems specific to the individual questions.

2.2 Question 1: Energy Volumes Purchased and Consumed

This question is an illustration of the conflict between obtaining detailed and accurate information, and achieving high coverage rates with a survey. In an attempt to gain detailed and otherwise unavailable data, the question asks for both purchased and used volumes for all energy forms. In addition, both electricity and natural gas volumes are subdivided into firm and interruptible service. This question is also of key importance to evaluate the other survey

results, since responses to many of the later questions are recorded in percentage form, requiring the volume numbers from Question 1 to produce the actual quantity responses.

As shown in Table 2.1, 4 of the 256 unique survey responses contained no information in Question 1. Furthermore, 251 of the records show no useful information in the "used volumes" columns. This indicates that companies were either unwilling or unable to produce the detailed data requested. Table 2.2 illustrates the results obtained from this question. These results are aggregated directly from the consulting company's report and have not been generated independently for this paper.

The importance of the distinction between purchased and consumed energy volumes depends on the intended use of the data. Obviously, actual consumption of energy relates more closely to the production process, whereas the purchase of energy is tied to energy market conditions. The low response to the "used energy" section may be partly due to poor structuring of the question or lack of instructions for answering.

It is not apparent in Question 1 how to treat self-produced or transformed energy forms. Should "used energy" encompass only volumes purchased plus net storage adjustments, or does used energy include self-produced, secondary energy forms such as spent pulping liquor and self-generated electricity? Some of the responses showed large discrepancies between purchased and used volumes, indicating that self-produced energy was included. For others, the differences could be accounted for by storage adjustments. Certain manufacturing companies consume considerable amounts of self-produced fuels. For energy-intensive industries, more than 50 percent of total energy requirements may be self-produced.[3] In Ontario, the industrial sector is responsible for 3 to 4 percent of total electricity generation.[4]

Finally, the information collected under the heading "other energy forms" appears to be of little use. Not only are these responses inadequate, but the recording of the information was inconsistent. The category was intended to capture volumes of purchased steam, wood, propane and other energy forms that are of lesser overall importance, but that may be a major energy carrier for a particular company or even industry. Again, there appears to have been confusion as to how to record secondary energy, since some companies included large volumes of presumably self-produced energy such as spent pulping liquor or coke oven gas. In addition, these volumes have been coded

TABLE 2.2

1987 ENERGY USE
(terajoules)

	Natural Gas		Electricity		Heavy	Light	
	Firm	Interruptible	Firm	Interruptible	Fuel Oil	Fuel Oil	Coal
Industries	146 831	89 375	100 524	15 259	35 716	1 696	139 321
Institutions	2 005	6 514	3 707	144	439	58	--
TOTAL	148 836	95 889	104 231	15 403	36 147	1 754	139 321

SOURCE: CERI Energy Research Ltd., *Energy Use Patterns and Boiler Characteristics of Large Energy Users in Ontario*, Multi-Client Study (Calgary, Alberta: CERI Energy Research Ltd., May 1989).

inconsistently, using up to five different codes for the same commodity. For example, propane is coded as propane, prop, prop. and pro. Although the computer code can take such inconsistencies into account, it is important to be aware of the problem, and it would be preferable to clean up the source data.

In summary, accurate and consistent responses to Question 1 are of crucial importance to the quality of data in the entire Section A. The question was too complex and poorly defined, requiring more detail than could be obtained, thereby detracting from the reliability of the results. In addition, coding inconsistencies rendered the "other" category of little value.

2.3 Question 2: End-Use of Energy

This question was designed to allocate energy use between the main end-use categories of boilers, direct-fired equipment and feedstock use. This is an issue that is poorly covered in Canadian data sources. The responses were reported in percentage form so that the total end-use of each fuel reported should add to 100 percent, providing a consistency check. The response rate to this question was 243 unique records, or approximately 65 percent. Table 2.3 provides the aggregate results as reported in the consultant's study. Again, these results have not been independently confirmed for this paper.

A closer scrutiny of the positive responses would eliminate several more records containing inconsistent data, for example where total use does not add to 100 percent. The desired level of accuracy was not specified, and this led to a wide discrepancy between responses. Some records show up to four decimal places while others have been rounded to the nearest 10 percent. The data contained in the "other" category is of no value without a revision of the variable names to ensure consistency in coding. Excluding all the data records with positive entries only in the "other" category leaves 213 records or 57 percent coverage.

Another problem with this question lies in the structural dependency on Question 1. The end-use of energy must necessarily correlate with the actual use of secondary energy as opposed to purchased primary volumes. As discussed in Section 2.1, this category in Question 1 was almost completely ignored. The only way to calculate volumes in end-use categories would be to approximate by multiplying the end-use percentages with the purchased volumes numbers. However, the percentage distribution across end-use

TABLE 2.3

INDUSTRIAL SECTOR
ENERGY USE BY END-USE CATEGORY
(percent)

	Natural Gas		Electricity		Heavy	Light	
	Firm	Interruptible	Firm	Interruptible	Fuel Oil	Fuel Oil	Coal
Boilers	34.0	50.1	3.4	3.3	59.5	26.3	3.3
Direct-Fired	52.6	42.2	29.9	32.8	39.4	62.3	10.5
Feedstock	11.4	7.7	N/A	N/A	0.0	0.0	48.9
Other	2.1	0.1	69.7	63.9	1.1	11.4	37.4
TOTAL	100	100	100	100	100	100	100

SOURCE: CERI Energy Research Ltd., *Energy Use Patterns and Boiler Characteristics of Large Energy Users in Ontario*, Multi-Client Study (Calgary, Alberta: CERI Energy Research Ltd., May 1989).

categories is in itself an interesting contribution to understanding industrial energy-use patterns.

In conclusion, this is an important question attempting to cover an area that is not well documented in Canadian data. The results as reported in the client report appear to be in accordance with expectations based on international experience. A much more complete coverage of the industrial sector would be desirable as a basis for any firm conclusions regarding end-use patterns. It would be crucial in a future questionnaire to clarify the distinction between primary and secondary, purchased and self-produced energy volumes in each question. With the above modifications, the percentage format would appear to be an appropriate and convenient way to record the data, but the question must specify the level of accuracy required.

2.4 Question 3: Switchability

The issue of switchability between energy forms is again very poorly documented in Canadian data. It is a topic of particular importance in determining the scope of short-term market flexibility. This is of interest to energy suppliers and also to regulators concerned with energy security and environmental emissions.

The main problem in addressing questions of switchability lies in defining the term. Obviously, if there are no limits to time and costs involved, every energy form is 100 percent flexible. It has to be determined whether the question is addressing a technical or an economic potential for switching. Is fuel-flexibility primarily determined by market forces or by equipment constraints?

In its most narrow definition, switchable energy would include only the volumes used in dual- or multiple-fuel burning equipment. These types of equipment can, and do, switch rapidly and at low cost, in response to relatively small price differentials between the alternative fuels. The survey attempted to cover a broader definition of switchability by specifying a one month time constraint. This presumably allows for simple and low-cost retrofit technologies to be implemented. The question that remains unanswered is what kind of economic incentive would be required to generate this volume of switching. It would be interesting to request information both on volumes switchable within 24 hours and within one month to gain insight into the relative size of these flexible fuel markets.

As shown in Table 2.1, the response rate of this question is again lower than the indicated 70 percent, as 104 of the 256 unique records contained only combinations of -99, zero and blanks in the entire table. A further 70 records had a positive number in the "other energy forms" section only. As for the earlier questions, the "other" category can not be easily calculated due to inconsistent coding. This leaves a total of 82 records containing one or more positive numbers, or an effective response rate of 22 percent. Although it is to be expected that only a subset of the survey population have dual-fuel capabilities, this response rate would appear to be low.

Previous attempts to estimate switchability have been motivated mainly by the question of energy security. The Energy Supplies Allocation Board have several times estimated the ability of industry to switch from oil to any other energy form.[5] The problem with these estimates is that they do not consider whether the flexible oil volumes can in fact be switched back to oil from the alternative fuel. In other words, they are estimates of our capability to switch off oil, but not necessarily of industry's true fuel flexibility. Special off-oil government programs and incentives have also been implemented at various times, and measures of their effectiveness have been estimated.[6]

The survey took a comprehensive approach to the issue. Question 3 is set up as a matrix allowing for all combinations of fuel switching between natural gas, heavy fuel oil, electricity, coal and "other." This approach errs on the side of being too comprehensive. First, equipment does not commonly switch between fossil fuels and electricity. It would be reasonable to limit the alternatives to fossil fuels. Secondly, the "other" category, while potentially useful, suffers severely from coding inconsistencies. The fact that heavy fuel oil is specified as the only fuel oil led many companies to specify switching between heavy and light fuel oil, with light oil in the "other" category. This accounts for the large number of records with positive information in the "other" category only. The usefulness of this data may be limited. Table 2.4 illustrates these switchability results as reported by the consulting company.

The matrix layout of the table to be filled in resembles very much that of Question 2. The fact that responses were requested in percentage form for this question as well, compounded this confusion. It appears that several respondents have attempted to make the rows add to 100 percent. It is uncertain whether the fuels listed are

TABLE 2.4

FUEL SWITCHING CAPABILITY OF INDUSTRIES
(percent)

Switchable To	Natural Gas	Electricity	Heavy Fuel Oil	Coal	Other
Switchable From:					
Natural Gas	N/A	0.1	21.5	4.0	39.8
Electricity	1.9	N/A	0.8	0.0	0.0
Heavy Fuel Oil	51.3	0.0	N/A	0.2	46.2
Coal	10.5	0.0	0.7	N/A	0.3

SOURCE: CERI Energy Research Ltd., *Energy Use Pattterns and Boiler Characteristics of Large Energy Users in Ontario*, Multi-Client Study (Calgary, Alberta: CERI Energy Research Ltd., May 1989).

actually 100 percent switchable, or if this is a result of such confusion between questions. Some records contain flexibility percentages that add to more than 100 percent. Again, it is difficult to say whether these are mistakes or whether there exists a substantial inventory of multiple fuel technologies.

Calculating the actual volumes switchable from the percentages reported becomes next to impossible in this database. The volumes reported in Question 1 include feedstock numbers while the switchability percentages in Question 3 do not. To get a reliable result one would have to subtract the feedstocks reported in Question 2 from the purchased volumes before applying the percentages to calculate switchable volumes. Given the low response rate to Question 3, the number of questionnaires that have reliable and complete data in all three of these questions becomes so small that the results are not reliable. The problem of variable accuracy and rounding of responses is also apparent for this question.

In summary, the matrix of possible switching patterns could be simplified by excluding electricity. The desired level of accuracy of the responses should be specified. A possible extension would be to differentiate between volumes switchable in 24 hours as well as some longer time period, recognizing that one month is a fairly long time horizon in industry.

Thought should also be given to whether it is desirable to measure switching between different grades of fuel oil. If this is considered an important aspect of flexible fuel markets, then light fuel oil should be specified as a separate category. If this aspect of fuel switching is not of interest, then "fuel oil" should be substituted for "heavy fuel oil." Either of these revisions would eliminate the disproportionate amount of data in the "other" category.

2.5 Question 4: Sulphur Content, Heat Content and Storage Capacities

This question records the sulphur and heat content of fuel oil, coal and "other," and also the storage capacity for these three fuel categories. Of the 256 unique records, 98 contained a positive entry in the sulphur content column, representing a 26 percent response rate. There were 99 positive records, or a 26.5 percent response rate for heat content, and 130 records, a 35 percent response rate, in the storage capacity section (see Table 2.1).

The data was checked for consistency with other sections of the questionnaire and appears to be well filled out. There were again some inconsistencies across records in coding the "other" fuel category. The main problem with this section would appear to be the low response.

With respect to storage capacity, this is one question where a consistently applied alternative code would have been useful. Companies may be reluctant to provide actual volume information, but the survey could still record whether storage capacities exist or not. As it now stands, the -99 code was so inconsistently used that no conclusion can be drawn from the non-positive entries.

2.6 Question 5: Self-Generation of Electricity

This question records total volumes of self-generated electricity. The volumes are further divided into two generation categories, distinguishing between hydro and cogeneration. Total volumes sold off-site are also recorded.

Of these, only 31 companies reported that electricity was generated on-site. Twenty-four companies provided the actual volumes of self-generation. These volumes have been converted from kilowatt-hours (kW.h) to terajoules (TJ) in the database, adding to a total of 11 557 TJ. This is a surprisingly high number, especially considering the small number of positive responses. Total industrial generation in Ontario in 1987, according to Statistics Canada, was just over 13 130 TJ, indicating that the survey has covered approximately 88 percent of industrial generation capacity.[7]

This coverage becomes even more surprising when the breakdown by generation category is considered. According to Statistics Canada, approximately 46 percent of Ontario's industrial self-generation is hydroelectricity. A further 31 percent is conventional steam generation, leaving approximately 23 percent for gas turbine generators. One would expect that cogeneration would be a smaller percentage again, representing a sub-set of the gas turbine generation category. The survey reports only 3525 TJ of hydrogeneration, or 30.5 percent of the total, while cogeneration represents 7792 TJ, or 67 percent of the total.

The generation categories seem to have been the cause of some confusion. Cogeneration and hydrogeneration cannot have been

intended to represent an exhaustive list of generation options. These categories were probably singled out as being of special interest. It appears that the questionnaires have been completed as if all self-generated electricity must fall into these two categories. However, even if "cogeneration" is taken to represent all thermal generation options, the balance between hydro and thermal generation is not in accordance with other empirical observations. Given the size of the volumes reported, the breakdown by category should conform to the existing data.

It must be concluded that an error has been made, either in reporting, converting or in coding the responses, and as a result the volumes represented in the database are suspect. Furthermore, this data adds little to already existing data sources. If the intent was to gain insight into electricity generation for the regions within Ontario, the number of responses was too low to allow for any extensive regional analysis.

2.7 Section B: The Boiler Inventory

Section B of the survey collected detailed information on the technical characteristics of Ontario's industrial inventory of boilers. The response rate was less than 50 percent, with 183 returned questionnaires, but those returned appeared to be fairly complete. The database contains information on 442 boilers in service, 109 on standby and 27 not in service. Table 2.5 reproduces the consulting company's results on the age structure of the boiler stock in the industrial sector.

TABLE 2.5

NUMBER OF BOILERS BY YEAR OF INSTALLMENT AND SECTOR

	<1950	1950-1959	1960-1969	1970-1979	>1979
Industries	78	94	109	107	61
Institutions	0	9	72	27	2
TOTAL	78	103	181	134	63

SOURCE: CERI Energy Research Ltd., *Energy Use Patterns and Boiler Characteristics of Large Energy Users in Ontario*, Multi-Client Study (Calgary, Alberta: CERI Energy Research Ltd., May 1989).

In terms of individual questions, 10 records are blank on the question of which energy form the boilers were designed to use, and 4 of these are also blank on which energy form the boilers are currently equipped to use. The response to questions of rated capacity, efficiency, pressure and typical load appear to be well answered and consistent with expectations. Tables 2.6 and 2.7 illustrate these results as reported by the consulting company for the industrial sector.

The last two questions ask for any planned conversion to another energy commodity and year of planned overhaul and replacement. The consulting report did not outline any results or analysis of these questions. The reason is probably the very low response rate. A total of 9 records indicated that there were plans to convert their boilers to another energy form, and only 4 of these gave a planned year of conversion. A slightly higher number of positive records, 26, reported a planned year of major overhaul or replacement. The low response rate on these two questions is of less concern, since capital investment budgets are subject to major changes over time.

The other data also suffers from coding inconsistencies. Presumably these were rectified in the modelling that produced the final results. Multiple codes have been used for some single energy form, such as RGAS, GAS and REF.GAS. Where several energy forms can be used, no consistent convention has been applied. For example, some records read: HFO/NG or HFO/BFG/COG, while others read HFO & NG or HFO (PITCH). Again, such inconsistencies can be overcome in the computer program, but it is important to be aware of the problem.

While Section B represents by far the most complete and consistent part of the survey data, the database as a whole remains unsatisfactory. There is a lack of consistency between Sections A and B, as several records that indicated multiple fuel capacity in Section B did not complete the switchability question in Section A. Also, in some cases, the boiler fuel reported in Section B is not consistent with end-use patterns reported in Section A. On the whole, it appears that Section B contains the most internally consistent and reliable data. In general, if significant differences exist between the two sections, the data in Section A should be disregarded.

An inventory of industrial boilers and their characteristics is an important contribution to public data sources. This database marks a significant beginning to the process of understanding the industrial steam-raising market in Canada. However, more data is required, for

TABLE 2.6

NUMBER OF BOILERS BY ENERGY COMMODITY IN USE VERSUS COMMODITY OF DESIGN

	Energy Commodity Equipped to Use					Design Total
	Wood	Coal	HFO	LFO	Natural Gas	
Original Energy Commodity of Design						
Wood	14	0	0	0	0	14
Coal	3	5	35	14	14	71
HFO	0	2	98	18	16	134
LFO	0	7	0	39	11	57
Natural Gas	0	0	25	51	76	152
Currently Equipped Total:	17	14	158	122	117	

TABLE 2.7

BOILER CHARACTERISTICS BY SECTOR

	Average Operating Efficiency (percent)	Efficiency at Rated Capacity (percent)	Average Operating Pressure (kPa)	Average Design Pressure (kPa)	Typical Summer Load (kg/h)	Typical Winter Load (kg/h)
Industries	79.6	80.9	2 162	2 690	41 004	49 167
Hospitals	77.0	79.0	834	1 424	2 659	7 504
Universities	79.8	81.6	848	1 288	21 700	21 700
TOTAL	79.4	80.8	1 870	2 387	38 133	45 946

SOURCE: CERI Energy Research Ltd., *Energy Use Patterns and Boiler Characteristics of Large Energy Users in Ontario*, Multi-Client Study (Calgary, Alberta: CERI Energy Research Ltd., May 1989).

example to correlate these boiler characteristics with actual energy volumes consumed and other quantitative data. Further data collection is therefore indicated before analytical applications are attempted.

Footnotes

[1]Canada, National Energy Board, *Canadian Energy Supply and Demand 1987-2005* (Ottawa, Ontario: NEB, September 1988).

[2]To calculate this number only the unique questionnaire numbers were included, eliminating the four duplications arbitrarily according to the record numbering. It serves as an approximation only.

[3]Merete Heggelund, *Industrial Natural Gas Demand*, Study No. 30 (Calgary, Alberta: Canadian Energy Research Institute, May 1989).

[4]Canada, Statistics Canada, *Electric Power Statistics*, Catalogue 57001 Monthly (Ottawa, Ontario: Statistics Canada, December 1988).

[5]Canada, Energy Supplies Allocation Board, Industrial and Commercial Fuel Switching Capabilities (Ottawa, Ontario: Energy Supplies Allocation board, 1981 and 1986).

[6]For example: Canada, Energy, Mines and Resources, Industrial Conversion Assistance Program (Ottawa, Ontario: EMR, 1988).

[7]Canada, Statistics Canada, *Electric Power Statistics*, Catalogue 57001 Monthly.

Chapter 3

CONCLUSIONS AND RECOMMENDATIONS

Since the sub-sections in Chapter 2 addressed conclusions specific to each question, this chapter is confined to the more general conclusions and recommendations.

With hindsight it is always easy to criticize and indicate areas for improvement. Any survey, especially one as large and data intensive as this one, will suffer from inconsistencies and produce some questionable results. However, the overall impression of this database is that these problems are so severe here that the data set is incapable of shedding much light on the energy use or equipment structure of large energy users in Ontario.

- The database is not a reliable source of information on the energy use of large companies and institutions in Ontario due to a combination of questionnaire design problems, low response rates, insufficient follow-up of responses and inappropriate or inconsistent coding conventions.

A notable exception to this is the Section B data on boiler characteristics. Boilers represent by far the most important type of capital equipment in the flexible fuel market. In order to properly apply an end-use or process type model to questions of actual and potential fuel switchability, and also to topics such as energy efficiency and cogeneration, detailed data on the characteristics of boilers by industries and regions would be a valuable contribution. The data requirements for process modelling that are perhaps the most difficult to satisfy relate to the age structure and capacities of the current stock of capital equipment.

- The boiler inventory section generated the most consistent and reliable part of the database. This data may be of interest for process modelling, where the age-structure, capacities and efficiencies of capital equipment is of great importance.

The survey attempted to address some very important and interesting questions. By subjecting the resulting database to a thorough evaluation, some recommendations for revisions to the sur-

vey have been formed. This chapter outlines suggestions for how the survey might be repeated with improved results.

The survey was preceded by a draft questionnaire that was tested on a sample consisting of five industrial companies and one hospital. A larger test sample may have led to a redesigned questionnaire and prevented some of the problems that were revealed in the database. Furthermore, if the intention was to eventually extend this database to cover every province, it would have been desirable to initially survey a province with a smaller and less diverse industrial base that Ontario. Tackling a smaller and more uniform sample first would have allowed for easy establishment of consistent coding conventions and a significant build-up of expertise. As noted in the introduction, a thorough understanding of the characteristics of the targeted establishments is vital to the success of a survey.

- A more extensive pre-test of the questionnaire and initial application to a smaller and less diverse sample is recommended.

Just as the target group must be well understood, it is important to have a clear idea of the purpose of the survey. This questionnaire erred on the side of complexity as a result of trying to cover too many different topics. In addition, the interdependency between responses to different questions must be fully understood. To accommodate this, the questionnaire must provide complete and straightforward directions and accurate definitions of all the variables involved. The most serious shortfalls in this area in the survey were (i) the lack of definitions and differentiation between purchased and used, and primary and secondary energy volumes; and (ii) the inflated volumes of cogeneration.

- All variables and relationships between variables in the questionnaire must be defined, understood and explained.

A survey is a costly and labour-intensive undertaking. For this reason, questions should focus on data that will not immediately become obsolete. Major capital installations, such as boilers, can be in service for decades.

The most consistent and reliable part of the database appears to be Section B. If further survey work is to be undertaken, it would make sense to let the boiler inventory form the basis for a new questionnaire. By focussing on <u>one</u> central question, such as

switchability, the questionnaire could be significantly shortened and simplified. At the present, Section B does not contain any volumetric data. Questions on amounts of fuel burned would follow naturally from the specification of equipment characteristics and capabilities.

- A revised questionnaire should centre on the characteristics of the boiler stock, incorporating quantitative energy consumption questions into the responses for age and operating characteristics of the current inventory of boilers.

The question on "energy fuels currently equipped to use" could also form the basis for an investigation of switchability. By formulating this question such that it captures all the fuels each boiler is equipped to use, the scope of dual- and multiple-fuel switching in its most narrow definition would be identified. The question could then be expanded by asking for additional volumes switchable in a one-month time period to cover a broader definition of switchability.

Because the questionnaire should include the entire battery of boilers which each company operates, the question of system flexibility could also be addressed. For example, if a company is operating electric boilers but is keeping natural gas boilers on stand-by, this represents another form of fuel flexibility that should be taken into account.

If desired, the boiler questionnaire could also be expanded to address existing cogeneration facilities. By collecting detailed data on operating pressures and efficiency, the data should also be capable of quantifying the potential for future cogeneration installations. This aspect of the questionnaire would require significant input from someone with both engineering experience and an adequate understanding of the manufacturing production processes.

In general, this survey has attempted to address some very important questions related to the end-use of energy in the Ontario manufacturing sector. The problems encountered in interpreting the data were mainly due to a lack of accurate definitions of variables and of the relationships between variables.

Energy use in production processes is inextricably tied to the energy-using equipment. The best way to collect accurate and reliable data would be to start with data on the equipment itself. Boilers are used in virtually every energy-intensive production process and

represent the most important type of capital equipment both for fuel switching and for cogeneration.

This database has made an important beginning in the collection of comprehensive, detailed and process-oriented energy utilization data. By learning from the shortcomings of this database, the survey could be repeated and extended with improved coverage and response rates.

APPENDIX A

QUESTIONNAIRES

1. **Company Questionnaire**
2. **Institution Questionnaire**

Quest.No____
SIC (1)____
SIC (2)____
EMP (1)____

SURVEY OF LARGE ENERGY USERS IN CANADA
ONTARIO SURVEY

The purpose of this questionnaire is to determine the energy use patterns of, and develop a boiler inventory for industries in Ontario. The database will be held by the Canadian Energy Research Institute, a private energy economics research organization. The information you provide on your Energy Use Patterns (Section A) will be available to the government clients in aggregate form only. Only the boiler inventory information (Section B) will be available to the government clients on an individual firm basis. All of the information provided will be publicly available in aggregate form on . Please complete Section A even if you do not have any boilers. Exclude fuel consumed for transport purposes from your energy consumption totals.

If this questionnaire has been received by the head office of a multi-plant company, please copy this form and complete a separate questionnaire for each plant. If you have any questions regarding the survey or how to complete the questionnaire, please call Charles Robb or Gordon Robb collect at (613) 731-6783.

PLEASE COMPLETE QUESTIONNAIRE AND RETURN BY FEBRUARY 29, 1988 TO:

CERI Energy Research Ltd.
c/o 1855 Beattie Avenue
Ottawa, Ontario
K1H 9Z9

THANK YOU FOR YOUR COOPERATION.

Company_____ Phone_____

Address_____ Postal Code_____

Plant Address_____

Plant Postal Code_____ Plant Phone_____

Contact Person_____ Phone_____

What was your total average number of employees in 1987? Include part-time and seasonal employees at their full-time equivalent (e.g., count 0.5 for one employee working part-time for the whole year). Total number of employees in 1987_____

A. Energy Use Patterns

1. Please indicate the total amount of firm and interruptible energy purchased and used by your plant in 1987. Include amounts purchased and used as feedstock.

	Total Amount Purchased		Total Amount Used	
Energy Commodity	Firm	Interruptible	Firm	Interruptible
Natural Gas (10^6m^3)	_____ 10^6m^3	_____	_____ 10^6m^3	_____
Electricity (kW.h)	_____ kW.h	_____	_____ kW.h	_____
Heavy Fuel Oil (litres)	_____ litres		_____ litres	
Light Fuel Oil (litres)	_____ litres		_____ litres	
Coal (metric tonnes)	_____ metric tonnes		_____ metric tonnes	
Other*(specify)_____	_____ (units)_____		_____ (units)_____	
Other*(specify)_____	_____ (units)_____		_____ (units)_____	

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*e.g., wood, propane, refinery gas, solid waste, chemicals, petroleum coke, etc.

Quest.No.____

2. Please estimate the percentage distribution among the uses listed below of the total amount of each type of energy commodity used by your plant in 1987. (Total amounts may be provided instead, if available. Please indicate the units used.)

Energy Commodity	Boilers	Direct-Fired Equipment	Feedstock	Other	Total
Natural Gas					
-firm	____%	____%	____%	____%	100%
-interruptible	____%	____%	____%	____%	100%
Electricity					
-firm	____%	____%	NA	____%	100%
-interruptible	____%	____%	NA	____%	100%
Heavy Fuel Oil	____%	____%	____%	____%	100%
Light Fuel Oil	____%	____%	____%	____%	100%
Coal	____%	____%	____%	____%	100%
Other*(specify)____	____%	____%	____%	____%	100%
Other*(specify)____	____%	____%	____%	____%	100%

3. What percentage of the current consumption of energy commodities (excluding feedstock consumption) by your plant's boilers and direct-fired equipment can be switched within a one-month period (apart from contractual obligations) to the other energy commodities listed?

Energy Commodity Consumed	%Switchable to Nat. Gas	%Switchable to HFO	%Switchable to Elect.	%Switchable to Coal	%Switchable to ____
Natural Gas	NA	____%	____%	____%	____%
Heavy Fuel Oil(HFO)	____%	NA	____%	____%	____%
Electricity	____%	____%	NA	____%	____%
Coal	____%	____%	____%	NA	____%
Other*____	____%	____%	____%	____%	____%

4. What was the sulphur content and heat content of the energy commodities used by your plant in 1987, and what is your plant's current total energy commodity storage capacity?

Energy Commodity	Sulphur Content	Heat Content	Current Storage Capacity
Fuel Oil	____%	____MJ/litre	____litres
Coal	____%	____MJ/tonne	____metric tonnes
Other*____	____%	____MJ/____	____(units)____

5. Did your plant generate electricity on-site in 1987? Yes( ) No( )

IF YES: How much electricity did your plant generate in 1987? ____kW.h
How much of the electricity was hydro generated? ____kW.h
How much of the electricity was cogenerated? ____kW.h
How much of the electricity generated was sold off-site? ____kW.h

6. Please specify the major products manufactured by your plant and (optional) your 1987 output of these products.

Products Manufactured	1987 Product Output (specify units)
(1)____	(1)____(units)____
(2)____	(2)____(units)____
(3)____	(3)____(units)____

*e.g., wood, propane, refinery gas, solid waste, chemicals, petroleum coke, etc.

B. BOILER INVENTORY

Quest.No.____

If your plant does not have boilers, please return your completed questionnaire in the envelope enclosed. If your plant does have boilers, please indicate the following characteristics for all boilers in your plant whether in service or not. Copy this sheet as often as required to record data for all boilers.

	Boiler 1	Boiler 2	Boiler 3
1. Operating status			
-in service	Yes( ) No( )	Yes( ) No( )	Yes( ) No( )
-standby	Yes( ) No( )	Yes( ) No( )	Yes( ) No( )
-not in service	Yes( ) No( )	Yes( ) No( )	Yes( ) No( )
2. Year installed	_____	_____	_____
3. Manufacturer	_____	_____	_____
4. Energy commodity originally designed to use	_____	_____	_____
5. Energy commodities currently equipped to use			
-commodity (1)	_____	_____	_____
-commodity (2)	_____	_____	_____
-commodity (3)	_____	_____	_____
6. Rated capacity			
-commodity (1)	_____kg/hr	_____kg/hr	_____kg/hr
-commodity (2)	_____kg/hr	_____kg/hr	_____kg/hr
-commodity (3)	_____kg/hr	_____kg/hr	_____kg/hr
7. Efficiency at rated capacity	_____%	_____%	_____%
8. Current operating efficiency	_____%	_____%	_____%
9. Design pressure (in psia or kPa)	_____psia _____kPa	_____psia _____kPa	_____psia _____kPa
10. Operating pressure (in psia or kPa)	_____psia _____kPa	_____psia _____kPa	_____psia _____kPa
11. Typical load-summer	_____kg/hr	_____kg/hr	_____kg/hr
-winter	_____kg/hr	_____kg/hr	_____kg/hr
12. Are there plans to convert from the energy commodity currently being used?	Yes( ) No ( )	Yes( ) No ( )	Yes( ) No ( )
-If yes, to what energy commodity?	_____	_____	_____
-Planned year of conversion	_____	_____	_____
13. Planned year of major overhaul or replacement	_____	_____	_____

PLEASE RETURN COMPLETED QUESTIONNAIRE BY FEBRUARY 29, 1988. THANK YOU.